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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Serial No. 09/973,685
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MAXIMUM TORQUE-PER-AMPERE
CONTROL OF A SATURATED SURFACE-
MOUNTED PERMANENT MAGNET
MACHINE

Examiner David W. Scheuermann

BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

Commissioner for Patents
P. O. Box 1450
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BRIEF FOR APPELLANT GENERAL MOTORS

General Motors Corporation is filing in triplicate this Brief to support the Appeal of Claims 1-4, 6, and 8-12, which the Office Action dated October 10, 2003, finally rejected. Please charge the fee required by this Brief and any other fees which may be due to Deposit Account No. 07-0960.

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I. REAL PARTY IN INTEREST

In this appeal the real party of interest is the assignee, General Motors Corporation.

II. RELATED APPEALS AND INTERFERENCES

There are no related appeals and interferences.

III. STATUS OF CLAIMS

Claims 1-4, 6, and 8-12 are under final rejection and are on appeal.

IV. STATUS OF AMENDMENTS

General Motors has filed no amendments since the final rejection of October 10, 2003.

V. SUMMARY OF INVENTION

Below is a Brief Summary discussing the objective features and advantages of the invention. Following the Brief Summary is a detailed summary complying with 37 C.F.R. 1.192(c)(3).

A. BRIEF SUMMARY

The present invention is a method and apparatus for increasing the torque of a surface-mounted permanent magnet machine or motor by using saturation-induced reluctance torque. At high stator current levels, when the effects of magnetizing saturation cannot be neglected, the two magnetizing inductances (L_d and L_q) in a vector control scheme are not equal, and additional torque can be obtained from the motor if the d-axis current is controlled to an optimal, non-zero value. The angle β is shown in Figure 1 of the present application as the vector component of the d and q axis currents. By varying the angle β , different current setpoints in the control scheme of the present invention may be used to control the electromagnetic torque of the motor, as L_d and L_q are not zero at relatively high stator current levels.

B. DETAILED SUMMARY

Claim 1 recites an electric motor control system (page 2, lines 7-9 and Figure 3) comprising: a stator for producing a magnetic field (page 3, lines 25-27 and Figure 2, reference number 12); a surface mount permanent magnet rotor rotated by said magnetic field (page 3, lines 25 through page 4, line 2 and Figure 2, reference number 14 and 18); a motor shaft coupled to said rotor (page 3, line 25 through page 4, line 2 and Figure 2, reference numbers 14 and 18); power electronics for controlling said magnetic field in said stator (page 4, lines 21-26 and Figure 3, reference number 22); wherein said power electronics controls the q-axis and d-axis current components for the electric motor (page 4, lines 3-28 and Figure 3, reference number 22); and a controller controlling said power electronics, said controller including a control block to control the d-axis current as a function of the angle β (page 4, lines 3-28 and Figure 3, reference numbers 22 and 24).

Claim 2 recites the electric motor control system of Claim 1 wherein said stator includes current carrying coils to generate said magnetic field (page 3, lines 25-27 and Figure 2, reference number 12).

Claim 3 recites the electric motor control system of Claim 1 wherein said surface mount permanent magnet rotor includes rare earth magnets (page 4, lines 1-2 and Figure 2, reference number 18).

Claim 4 recites the electric motor control system of Claim 1 wherein said power electronics comprises a voltage source inverter (page 4, lines 5-10 and Figure 3, reference number 22).

Claim 6 recites a method of controlling an electric motor (page 2, lines 7-9 and Figure 3) comprising: providing an electric motor having a wound stator, a rotor magnetically coupled to said wound stator, said rotor including surface mount permanent magnets (page 3, line 25

through page 4, line 2 and Figure 2, reference numbers 10, 12, 14, and 18); controlling q-axis current in the stator (page 4, lines 3-28 and Figure 3, reference numbers 24-36); controlling d-axis current in the stator (page 4, lines 3-28 and Figure 3, reference numbers 24-36); and wherein the step of controlling the q-axis current in the stator comprises controlling the q-axis current as a function of the angle β (page 4, lines 10-16 and Figure 3, reference number 24).

Claim 8 recites the method of Claim 6 wherein the step of controlling the d-axis current in the stator comprises controlling the d-axis current as a function of the angle β (page 4, lines 10-16 and Figure 3, reference number 24).

Claim 9 recites the method of Claim 6 further comprising the step of controlling the position of the electric motor (page 4, lines 25-28 and Figure 3, reference number 40).

Claim 10 recites a method of controlling an electric motor (page 2, lines 7-9 and Figure 3) comprising: providing an electric motor having a wound stator, a rotor magnetically coupled to said wound stator, said rotor including surface mount permanent magnets (page 3, line 25 through page 4, line 2 and Figure 2, reference numbers 10, 12, 14, and 18); providing a vector controller and voltage switched inverter to provide stator current to the wound stator (page 4, lines 3-28 and Figure 3, reference numbers 24-36); controlling the q-axis and d-axis current components of the stator current to control the torque of the electric motor (page 4, lines 10-15 and figure 3, reference number 24); and calculating the d-axis current setpoint as a function of the angle of the stator current vector with reference to the q-axis (page 4, lines 10-15 and figure 3, reference number 24).

Claim 11 recites the method of Claim 10 further comprising the step of determining the position of said rotor (page 4, lines 25-28 and Figure 3, reference number 40).

Claim 12 recites the method of Claim 11 further comprising the step of determining the actual current of the electric motor (page 4, lines 17-18 and Figure 3, reference number 38).

VI. ISSUES

Whether Claims 1-4, 6, and 8-12 contained subject matter which is not enabled by the specification.

Whether Claims 1-2, 4, 6, and 8-12 are unpatentable over U.S. Patent No. 6,378,367 to Iijima et al. in view of U.S. Patent No. 5,920,161 to Obara et al.

VII. GROUPING OF CLAIMS

General Motors Corporation groups the claims as follows for this Appeal. Claims 1-4 comprise a first group, Claim 6 comprises a second group, Claim 8 comprises a third group, Claim 9 comprises a fourth group, Claim 10 comprises a fifth group, Claim 11 comprises a sixth group, and Claim 12 comprises a seventh group. Group One patentably differs from groups one through seven, in that group one includes limitations for controlling the d-axis current as a function of the angle β . Group two patentably differs from groups one and three through seven, in that group two includes limitation for controlling the q-axis current as a function of the angle β . Group three patentably differs from Groups one, two, and four through seven, in that Group three includes limitations for controlling the q-axis and d-axis currents as a function of the angle β . Group four patentably differs from groups one through three and groups five through seven, in that group four includes limitations for controlling the position of the motor. Group five patentably differs from groups one through four and groups six and seven, in that group five includes method limitations for calculating the d-axis current setpoint as a function of the stator current vector with respect to the q-axis. Group six patentably differs from groups one through five, in that group five includes limitations for determining the position of the rotor. Group seven patentably differs from groups one through six, in that group seven includes limitations for determining the current of the electric motor. Groups one through seven do not stand or fall together and are patentably different.

VIII. ARGUMENT

A. CLAIM REJECTIONS UNDER 35 U.S.C § 112

1. The Claims of the present invention are enabling to a person of ordinary skill in the art and supported by the specification.

On page 3 of the Final Office Action, the Examiner stated it is not clear how angle β is varied and determined after the initial assigned value of zero has been set. As is known in the art of electric motor vector control and illustrated in Figures 1 and 4 of the present invention, the switching patterns of a three phase power inverter are transformed into the d-q coordinate frame representing the spatial vector sum of the three phase voltage. To provide background for the Examiner, the goal of vector control is to provide independent control of the flux and torque producing elements in an AC motor. The phase currents are mapped as a vector into a two axis coordinate system (d-q), such that the motor current is broken down into a magnetizing component and a torque component, analogous to a DC motor.

Figure 1 of the present invention clearly illustrates angle β and its relationship with the i_d , i_q and I_s . The transformation at block 24 is executed as a function of the angle β made by the stator current I_s with the q-axis. By increasing the value of i_d , the value of β is increased. i_d and i_q are the d and q axis current components generated by the space vector modulation component 36 of the present invention to control the power electronics/transistors of the inverter 22. The angle β is varied by control block 24 as any value in a computer program may be varied, hence the name variable. For example if a line has a function $y = mx + b$, the variable x may be varied. The specification on page 4 of the application clearly shows the functions:

$$i_q^* = I_s \cos\beta$$

$$i_d^* = I_s \sin\beta$$

Accordingly the angle β may be varied to generate different values of i_q and i_d dependent on the requested torque, as would be done in a computer program, again hence the name variable. If the actual physical interpretation of the mathematical functions is the enablement issue, Applicants point to the inverter 22 as the electronic component which generates the current to the motor 10.

Inverters and vector control for three phase motors are well known by any person of ordinary skill in the art. Federal Circuit decisions have emphasized that “[a] patent need not disclose what is well known in the art.” *In Re Wands*, 8 USPQ2d 1400, (1402) (Fed. Cir. 1988).

B. THE SCOPE AND CONTENT OF THE PRIOR ART: CLAIM REJECTIONS UNDER 35 U.S.C §103

On page 4 of the Final Office Action of October 10, 2003, the Examiner rejected Claims 1-2, 4, 6, and 8-12 under 35 USC §103 as being unpatentable over Iijima et al., US 5,936,378 in view of Obara et al., US 5,920,161

1. Iijima et al.

a. Iijima et al. generally discloses a vector motor controller and drive unit for supplying power to the stator windings of a motor.

b. Iijima et al. does not teach or suggest controlling the d and/or q axis current components as a function of the angle β .

On page 4 of the Final Office Action, the Examiner stated that Iijima et al. does not expressly disclose a control block to control either the d or q axis current components as a function of β . Applicants respectfully agree with this statement. In column 1, lines 48-51, Iijima et al. expressly discloses that the d and q axis magnetizing components are equal and therefore the second term of equation 2 in Iijima et al. is zero. Iijima et al. is silent with respect to, and in fact teaches away from, controlling the d or q axis components as a function of β , as Iijima expressly assumes that the d and q (L_d and L_q) axis magnetizing components are zero. The present invention recognizes that at high stator current levels, when the effects of magnetic saturation cannot be neglected, the two magnetizing inductances will have different values where L_d is not equal to L_q . In the present case, the difference (L_d-L_q) is not zero, and additional torque

can be obtained from the motor by controlling the d and q axis current components as a function of β .

c. Iijima et al. teaches away from controlling the d and/or q axis current components as a function of the angle β .

Iijima et al. is silent and in fact teaches away from controlling the d or q axis components as a function of β as Iijima et al. expressly assumes that the d and q (L_d and L_q) axis magnetizing components are zero. The present invention recognizes that at high stator current levels, when the effects of magnetic saturation cannot be neglected, the two magnetizing inductances can have different values where L_d is not equal to L_q . In these cases, the difference ($L_d - L_q$) is not zero, and additional torque can be obtained from the motor by controlling the d and q axis current components as a function of β .

2. Obara et al.

a. In general Obara et al. discloses a driving system for permanent magnet motor.

b. Obara et al. and Iijima et al., singly or in combination, do not teach or suggest the present claimed invention.

On page 4 of the Final Office Action the Examiner stated that Obara et al. discloses controlling the d or q axis current components as a function of the angle β . Applicants respectfully disagree with the Examiner, Obara et al. discloses a standard vector control block 304 as is known in the art. Obara et al. is completely silent with respect to controlling the d or q axis current components as a function of the angle β . In fact Obara et al. only determines the angle β of the synchronous generator, as disclosed in column 5, lines 13-15. Obara et al. generates control of the electric motor based on the phase difference angle δ as seen in Figure 3 of Obara et al. The combination suggested by the Examiner does not teach or suggest the claims of the present invention.

The Examiner by combining Iijima et al. and Obara et al. is involved in improper speculation and conception of an invention based upon the cited prior art. In order to establish a

prima facie case of obviousness, the Examiner must identify a suggestion or motivation to modify the teachings of the cited references to achieve the claimed invention. *In re Kotzab* 55 USPQ2d 1313, 1316-1317 (Fed. Cir. 2000). A critical step in analyzing the patentability of claims pursuant to section 103(a) is casting the mind back to the time of the invention to consider the thinking of one of ordinary skill in the art, guided only by the prior art references and the then-accepted wisdom in the field. Close adherence to this methodology is especially important in cases where the very ease with which the invention can be understood may prompt one "to fall victim to the insidious effect of hindsight syndrome wherein that which only the invention taught is used against its teacher." *In Re Kotzab*, 217 F.3d 1365. The Examiner has fallen victim to hindsight reconstruction and has also ignored the elements of the claimed invention and failed to explain how and why the claimed subject matter is rendered unpatentable over the prior art and point out where each of the specific limitations recited in the rejected claims is found in the prior art relied on.

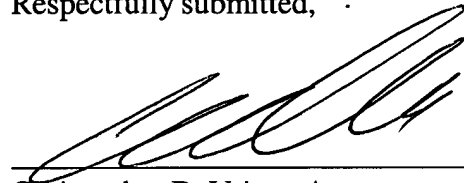
c. The suggested combination of Iijima et al. and Obara et al. by the Examiner is improper.

Iijima et al. is silent and in fact teaches away from controlling the d or q axis components as a function of β , as Iijima expressly assumes that the d and q (L_d and L_q) axis magnetizing components are zero, as previously discussed. The suggested combination of the Examiner is improper, references cannot be combined where the reference teaches away from their combination. See MPEP Section 2145.

SUMMARY

Iijima et al. and Obara et al. singly or in combination do not teach or suggest the present claimed invention. Furthermore, the combinations suggest by the Examiner of Iijima et al. and Obara et al. is improper. The Examiner has failed to explain how and why the claimed subject matter is rendered unpatentable over the prior art and point out where each of the specific limitations recited in the rejected claims is found in the prior art relied on. Applicants therefore request allowance of independent Claims 1-4, 6, and 8-12.

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'Christopher DeVries', is written over a horizontal line.

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Appendix A

1. (previously presented) An electric motor control system comprising:
a stator for producing a magnetic field;
a surface mount permanent magnet rotor rotated by said magnetic field;
a motor shaft coupled to said rotor;
power electronics for controlling said magnetic field in said stator;
wherein said power electronics controls the q-axis and d-axis current components for the electric motor; and
a controller controlling said power electronics, said controller including a control block to control the d-axis current as a function of the angle β .
2. (original) The electric motor control system of Claim 1 wherein said stator includes current carrying coils to generate said magnetic field.
3. (original) The electric motor control system of Claim 1 wherein said surface mount permanent magnet rotor includes rare earth magnets.
4. (original) The electric motor control system of Claim 1 wherein said power electronics comprises a voltage source inverter.
5. (cancelled)
6. (previously presented) A method of controlling an electric motor comprising:
providing an electric motor having a wound stator, a rotor magnetically coupled to said wound stator, said rotor including surface mount permanent magnets;
controlling q-axis current in the stator;
controlling d-axis current in the stator; and

wherein the step of controlling the q-axis current in the stator comprises controlling the q-axis current as a function of the angle β .

7. (cancelled)

8. (original) The method of Claim 6 wherein the step of controlling the d-axis current in the stator comprises controlling the d-axis current as a function of the angle β .

9. (original) The method of Claim 6 further comprising the step of controlling the position of the electric motor.

10. (previously presented) A method of controlling an electric motor comprising:
providing an electric motor having a wound stator, a rotor magnetically coupled to said wound stator, said rotor including surface mount permanent magnets;
providing a vector controller and voltage switched inverted to provide stator current to the wound stator;
controlling the q-axis and d-axis current components of the stator current to control the torque of the electric motor; and
calculating the d-axis current setpoint as a function of the angle of the stator current vector with reference to the q-axis.

11. (original) The method of Claim 10 further comprising the step of determining the position of said rotor.

12. (original) The method of Claim 11 further comprising the step of determining the actual current of the electric motor.

13. (cancelled)